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Jawaharlal Nehru
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IS 7906-6 (1978): Helical Compression Springs, Part VI: Design and Calculations for Springs Made from Rectangular Section Bar-Steel [TED 21: Spring]

"ज्ञान से एक नये भारत का निर्माण"
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"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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Indian Standard

HELICAL COMPRESSION SPRINGS

PART VI DESIGN AND CALCULATIONS FOR SPRINGS MADE FROM RECTANGULAR SECTION BAR-STEEL

1. Scope — Lays down calculations for design of helical compression springs made from rectangular or square section wire or bar.

1.1 This standard applies to springs of special designs where it becomes imperative to use them due to space limitations. Springs made from rectangular section bar should be avoided as far as possible as the springs made from circular section bar can be stressed to the same values for a lower weight of material used and for shorter overall length. The design of such springs is based on the final rectangular section. Suitable trapezoidal section may have to be selected to arrive at final rectangular section.

2. Terminology — Following symbols shall apply (*see also* figure).
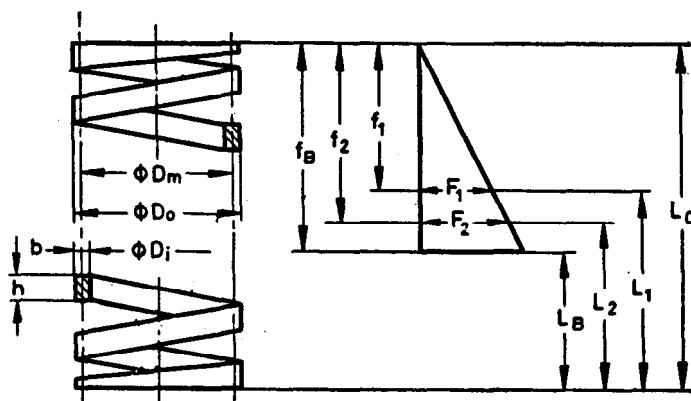
b = Side of cross-section perpendicular to axis of the spring, mm

f_1, f_2 = Spring deflections corresponding to axial loads F_1, F_2, mm

$f_B = L_0 - L_B$ = Spring deflection in mm, related to axial load F_B, mm

h = Side of cross-section parallel to axis of the spring, mm

i_t = Number of working coils

i_g = Total number of coils

$w = \dfrac{D_m}{b}$ = Coil ratio ($w > 4$)

D_o = External coil diameter, mm

D_i = Internal coil diameter, mm

D_m = Mean coil diameter, mm

F_1, F_2, etc = Axial load, related to load lengths, L_1, L_2, etc, N

F_B = Axial load related to length of compressed spring L_B, N

G = Modulus of rigidity, N/mm²

L_0 = Length of unloaded spring, mm

L_1, L_2 = Load lengths of spring, mm

L_B = Length of compressed spring (all coils closed), mm

R_s = Shear stress under load F, N/mm²

R_sB = Shear stress under load F_B, N/mm²

$S_c = \dfrac{\triangle F}{\triangle f}$ Spring rate, N/mm

ε = Elasticity (resilience) coefficient, dependent on ratio of cross-section side lengths b/h or h/b.

ψ = Stress coefficient, dependent on ratio of cross-section side lengths b/h or h/b and on coil ratio w.

3. Type of Coiling — Springs made from rectangular section bar are used with advantage for the types of coiling given in **3.1** and **3.2**.

3.1 *Coiled on Edge* — In this case longer side of the cross-section is perpendicular to the axis of the spring. This type of coiling enables large deflections, short block lengths and a high ratio of internal to external coil diameters.

3.2 *Flat Coiled* — In this case the longer side of the cross-section is parallel to the axis of the spring. This type of coiling enables large free lengths and low ratios of external to internal diameters.

4. Loading — Spring made from rectangular section bars are usually used to obtain the maximum load capacity for a given space. Consequently such springs are often highly stressed. Long service cannot be expected under such conditions, especially if the range of stress is high as well as the stress at maximum load.

5. Design Formulae

5.1 *Shear Stress, R_s*

$$R_s = \frac{\psi \times D_m}{b \times h \times b \times h} \times F$$
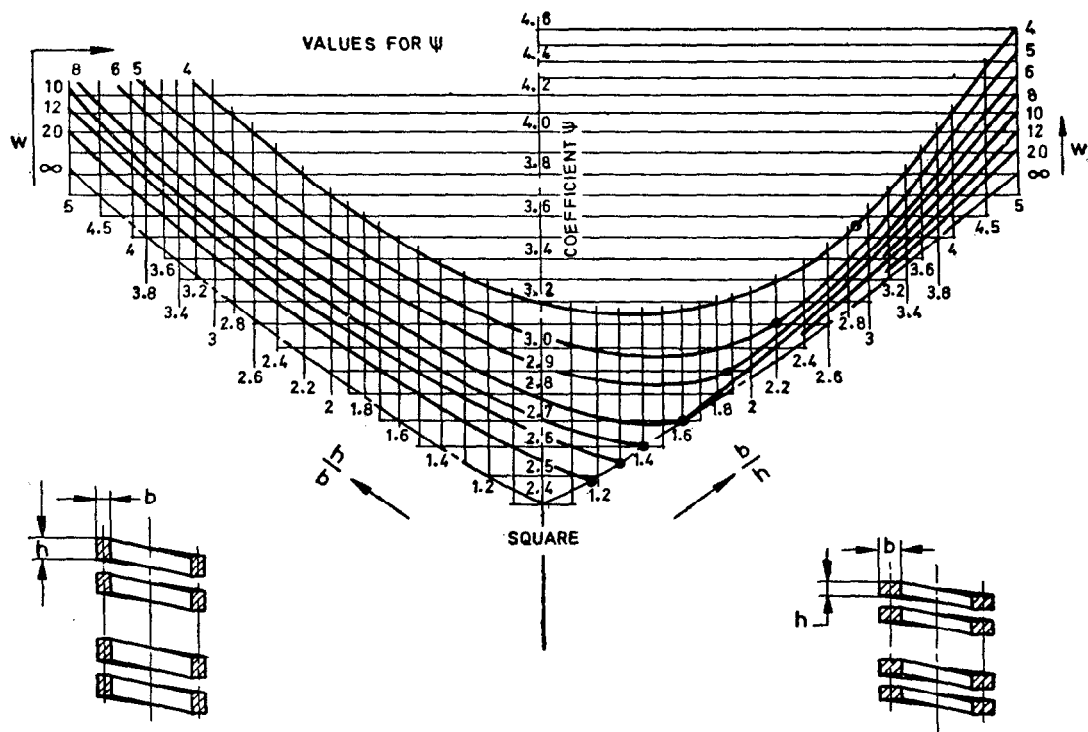
5.2 *Spring Deflection, f*

$$f = \frac{\varepsilon \times D_m{}^3 \times i_f}{b^2 \times h^2 \times G} \times F$$

5.3 *Number of Turns*

$$i_f = \frac{b^2 \times h^2 \times G}{\varepsilon \times S_c \times D_m{}^3}$$

$$i_g = i_f + 2$$

5.4 Values of ψ and ε are given in figure below.

Values for ε:

$\dfrac{b}{h}$ or $\dfrac{h}{b}$	1	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2
ε	5·59	5·61	5·67	5·77	5·88	6·02	6·17	6·33	6·50	6·68	6·87

$\dfrac{b}{h}$ or $\dfrac{h}{b}$	2·2	2·4	2·6	2·8	3	3·2	3·4	3·6	3·8	4	4·5	5
ε	7·26	7·67	8·09	8·51	8·95	9·39	9·83	10·28	10·73	11·19	12·33	13·48

5.5 Examples of design of compression springs made from square and rectangular section material are as follows:

Example A

A-1. Design of cold coiled compression spring made from square section material, subjected to a static or infrequently varying load.

A compression spring is required to meet a load $F_1 = 250$ N at $L_1 = 50$ mm and $F_2 = 400$ N at $L_2 = 40$ mm. The space available permits a maximum outside coil diameter $D_o = D_m + b = 30$ mm.

A-1.1 Spring rate S_c from F_1, F_2 and L_1, L_2 is obtained as under:

$$\frac{F_2 - F_1}{L_1 - L_2} = \frac{150 \text{ N}}{10 \text{ mm}} = 15 \text{ N/mm}$$

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Moreover, from load/deflection line we can obtain the free length as under:

$$f_1 = F_1 \left(\frac{f_2 - f_1}{F_2 - F_1} \right) = 250 \text{ N} \times \frac{10}{150} = 16\cdot66 \text{ mm}$$

The free length of the spring is therefore $L_0 = 50 + 16\cdot66 \text{ mm} = 66\cdot66 \text{ mm}$

A-1.2 Assuming a mean Dia $D_m = 26$ mm, so that the side length of the section is restricted to $b = h < 4\cdot0$ mm.

From formula 5.3

$$\frac{h^2 b^2}{i_f} = \frac{\varepsilon \times S_c \times D_m^3}{G}$$

$$= \frac{5\cdot59 \times 15 \times 26^3}{81\,370}$$

$$\frac{h^2 b^2}{i_f} = \frac{h^4}{i_f} = 18\cdot11$$

$$\therefore \quad i_f = \frac{h^4}{18\cdot11} \text{ since } h = b$$

A-1.3 Assuming a minimum space S_a between individual coils as $0\cdot1 \times h$ since the specified length $L_2 = 40$ mm, we have the following:

$$(i_f + 2) h + i_f \times S_a = 40$$

$$(i_f h + 2h) + (i_f \times 0\cdot1\,h) = 40$$

$$i_f = \frac{10}{11} \left(\frac{40}{h} - 2 \right)$$

$$\therefore \frac{10}{11} \left(\frac{40}{h} - 2 \right) = \frac{h^4}{18\,11}$$

The result of the graphic solution is

$$b = h = 3\cdot5$$

$$i_f = 7\cdot3$$

$$i_g = 7\cdot3 + 2 = 9\cdot3 \text{ and } L_B = 32\cdot55 \text{ mm}$$

Coil ratio $W = \dfrac{26}{3\cdot4} = 7\cdot65$

A-1.4 Checking the maximum shear stress from formula 5.1

$$R_s = \frac{\psi \times D_m \times F_{Max}}{h^3}$$

$$= \frac{2\cdot4 \times 26 \times 512}{3\cdot5^3}$$

$$= 745 \text{ N/mm}^2$$

The above stress is safe and plain carbon spring steel wire can be chosen for the manufacture of the springs.

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Example B

Design of a cold coiled helical spring made from rectangular section wire subjected to a static or infrequently varying load.

B-1. A compression spring is required to meet a load $F_1 = 530$ N at $L_1 = 55$ mm and $F_2 = 1\,060$ N at $L_2 = 45$ mm. The space available permits a maximum outside dia $D_o = D_m + b$ of 25·5 mm and a rod of 14 mm should pass freely inside the spring in fitment.

B-1.1 Spring rate S_c from F_1, F_2 and L_1, L_2 is obtained as under:

$$\frac{F_2 - F_1}{L_1 - L_2} = \frac{530 \text{ N}}{10 \text{ mm}} = 53 \text{ N/mm}$$

From load/deflection line we can obtain the free length as under:

$$f_1 = F_1 \left(\frac{f_2 - f_1}{F_2 - F_1} \right)$$

$$= 530 \times \frac{10}{530} = 10 \text{ mm}$$

The free length of the spring is therefore

$$L_o = 55 + 10 = 65 \text{ mm}$$

B-1.2 Assuming a mean dia of $D_m = 20$ and $b = 5$ and $h = 3.5$ we shall calculate the number of coils from formula 5·3

$$i_f = \frac{b^2 \times h^2 \times G}{\varepsilon \times S_c \times D_m^3}$$

$$= \frac{5^2 \times 3.5^2 \times 81\,370}{5.9 \times 53 \times 20^3}$$

$$= 10 \text{ coils}$$
$$i_g = 10 + 2 = 12$$

Solid height $L_B = 12 \times 3.5 = 42.0$ mm

Assuming minimum space S_a between individual coils as 0·1 × h, the required total clearance is 0·1 × 3·5 × 10 = 3·5 mm whereas clearance available between L_2 and L_B is only 3 mm. Hence try alternative thickness of wire.

Choose a thickness say 3·45 mm and recalculate the number of coils

$$i_f = \frac{5^2 \times 3.45^2 \times 81\,370}{5.95 \times 53 \times 20^3}$$

$$= 9.6$$
$$i_g = 11.6 \qquad L_{BL} = 40 \text{ mm}$$

B-1.3 Check for maximum shear stress R_{sB} from formula 5·1

$$R_{sB} = \frac{\psi \times D_m \times F_B}{b \times h \times b \times h}$$

$$= \frac{3.15 \times 20 \times 1\,325}{5 \times 3.45 \times 5 \times 3.45}$$

$$= 1\,166 \text{ N/mm}^2$$

In view of the above high stress, material chosen should be alloyed spring steel wire such as chrome silicon or chrome vanadium spring steel wire.

6. Shot Peening of Springs — Springs made from rectangular section bars may be shot peened to increase their life. Lower stress range shall be used for the purposes of calculations even when the springs are shot peened.

EXPLANATORY NOTE

This standard is one of a series of Indian Standards on the design, calculation and specifications of helically coiled springs. Other standards in this series are:

IS : 7906 (Part I)-1976   Helical compression springs: Part I Design and calculation for springs made from circular section wire and bar

IS : 7906 (Part II)-1975   Helical compression springs: Part II Specification for cold coiled springs made from circular section wire and bar

IS : 7906 (Part III)-1975   Helical compression springs: Part III Data sheet for specifications for springs made from circular section wire and bar

IS : 7906 (Part V)-1975   Helical compression springs: Part V Specification for hot coiled springs made from circular section bar

IS : 7907 (Part I)-1976   Helical extension springs: Part I Design and calculation for springs made from circular section wire and bar

IS : 7907 (Part II)-1976   Helical extension springs: Part II Specification for cold coiled springs made from circular section wire and bar

IS : 7907 (Part III)-1975   Helical extension springs: Part III Data sheet for specification for springs made from circular section wire and bar

In the preparation of this standard, considerable assistance has been derived from DIN 2090-1971 Helical compression springs made of rectangular steel, calculation, issued by Deutsches Institut für Normung.